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EVALUATION AND INNOVATION IN THE NAVY'S

PERSONNEL RESEARCH LABORATORIES

I. Preliminary Considerations

by

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ABSTRACT:

Characteristics of R&D laboratories are reviewed with emphasis on Federal laboratories. Dimensions of the scientist-laboratory interface and their potential relationships to R&D products are examined. The purpose, need, and approaches to evaluation of laboratory effectiveness are reviewed with emphasis on advisory panels and criteria for evaluation. Recommendations are made for peer-rating the utility of Navy personnel research programs from the standpoint of consumer and producer. Recommendations are also made for a systematic analysis of the internal environment of the Navy's personnel research laboratories as a basis for management decisions and programs.

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## PREFACE

This report deals with a research project between the sponsoring activity, the Personnel Research Division of the Bureau of Naval Personnel, and the Naval Postgraduate School. The topics examined in this report are: (1) Current procedures and recommended, improved procedures for evaluating the performance and effectiveness of the Navy Personnel Research and Development Laboratory and the Navy Personnel and Training Research Laboratory and (2) administrative and managerial practices for encouraging greater application of new research techniques and procedures in the aforementioned laboratories. Subsequent reports will deal with the further development and application of evaluative procedures, effectiveness measures, and organizational principles for personnel and training research.

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## I. INTRODUCTION

The two problems analyzed in this report are methods for evaluating the performance effectiveness of the Navy's in-house personnel research laboratories and means for improving their performance through the adoption and application of new techniques and procedures. These two problems can be considered together since they are related to the more general question, What characterizes an effective, in-house, Federal laboratory? They are related to this question because, first, the characteristics of an effective laboratory could provide the basis for devising criteria to evaluate the effectiveness of a given laboratory. And such characteristics, when known, might also provide guidance for recommending managerial and administrative practices to enhance the effectiveness of a particular laboratory through the use of new and innovative procedures.

Accordingly, the approach taken in this report is to begin with the identification of salient features of organizational climates that appear to be important to effective performance within research and development (R&D) laboratories. Next, the environment or climate of Federal, in-house laboratories will be examined. Following this, attempts to assess and evaluate the effectiveness of R&D organization will be examined with particular reference to in-house laboratories. Finally, the specific procedures currently in use to evaluate the effectiveness of the Navy's in-house, personnel research activities will be reviewed, and recommendations will be made for improved procedures based on the

information developed in the preceding investigation.

Recommendations for administrative and managerial practices to foster the adoption and application of new research techniques and procedures in the Navy's personnel research laboratories will arise as a by-product of the attempt to identify evaluation criteria and methods for assessing the effectiveness of laboratories in the manner contemplated.

## II. CHARACTERISTICS OF RESEARCH AND DEVELOPMENT LABORATORIES

### A. GENERAL TRENDS

Leaving undefined for the present what constitutes effectiveness in R&D activities, it seems appropriate to assume that managerial and organizational practices that are conducive to effective operations in any type of organization are also applicable to R&D organizations, such as laboratories. This assumption is examined in detail by Argyris (1968) in its negative aspects. He explains how the detrimental features of a typical pyramidal organizational structure can be magnified in the dynamic life of an R&D organization. The thrust of his argument is that typical pyramidal organizations, when imposed on an R&D activity, may be conducive to the steady deterioration of the activity. The deterioration is primarily the result of improper controls imposed by the upper levels of the organization that are based on mistrust, antagonism, and defensiveness. As a result, the system becomes increasingly rigid; less competent personnel reach upper levels of the organization; accurate information ceases to flow through the system; paternalism begins to flourish; more time is spent on generating valid, perhaps, but not very important information; and nonresearch activities -- "selling," budgets, hiding bad news from the top -- begin to take precedence over research activities. The increasing frustration of the scientists in the organization is reflected by hesitating to take on responsibility and making tangential demands for space, equipment, assistants, travel to professional meetings, and the like. Good scientists leave the organization. As the

R&D organization that is locked in to this deteriorating process grows older, top management becomes disenchanted with it. Increasing . . .

intervention by the line departments, tighter research budgets, more systematic evaluation of research, more rigorous (hopefully) quantitative indices for evaluating research payoff, more use of charts to control the flow of research, closer link with the marketplace and a weaker tie with basic research, and finally, an increase in the use of top-level committees to oversee research can be expected. (Argyris, 1968, p. 353.)

The positive side of this argument is to design the controls, organizational structures, and leadership styles so that the participants ". . . may give of themselves rather than give up themselves" (Argyris, 1968, p. 347). The basis for designing such controls rests in openness, respect for individuality, trust, concern, and a willingness to permit risk-taking and innovation.

Controls, of course, imply pressure regardless of whether the controls are good or bad, positive or negative. To most persons, pressure in a job is an indication of undesirable stresses. In fact, the often asked question about an individual is his ability to stand up under pressure. Thus, a logical next step, following Argyris' critical appraisal of controls in R&D organizations, is an examination of the role of pressure. Should pressure be entirely undesirable? If so, how are controls to be exercised? Merely through reward systems? The question, according to Hall and Lawler (1971), is not whether pressure is good or bad but to determine when pressure is helpful and when it is dysfunctional. They state that healthy persons have a need to experience internal pressure and will create it if the environment fails to provide it.

In order to identify healthy pressures and their beneficial uses, it is necessary to distinguish between pressure and such terms as conflict, stress, tension, anxiety, and strain. To Hall and Lawler, job pressures are forces a person experiences which motivate him to behave in particular ways on the job, and pressure is the experience of a particular force. Strain, conflict, and similar conceptions represent the opposition of two or more pressures. With pressure thus defined, their research identified three kinds of pressure that were mentioned from laboratory to laboratory with considerable agreement as to their importance to research personnel. These were time, quality, and financial responsibility. Time was a felt need to meet schedules and deadlines, and it was typically externally imposed. Quality pressure was a concern for doing a good technical job and seemed to be generated by the researchers themselves, along with their colleagues. And finally, financial responsibility was felt as a concern for the financial goal-attainment of the organization as a whole.

These pressures were then related by Hall and Lawler (1971) to the satisfaction and job involvement of the research worker and to the effectiveness of the organization. Quality pressure was related positively to both job involvement of the individual professionals and to the technical effectiveness of their laboratories. Job involvement was also related to laboratory effectiveness. Financial responsibility pressure was significantly correlated with both laboratory effectiveness and the satisfaction of the researcher's need for autonomy. The impli-

cation here was that the more a person helps to support himself and his organization financially, the less dependent he is on the organization. Time pressure, while not negatively related to any of the criteria, was not related in a systematic way to researcher needs or to laboratory effectiveness.

Hall and Lawler (1971) conclude:

. . . the most effective organizations are those in which the professional value of technical excellence and/or the organizational value of financial responsibility are internalized by the system as a whole. These two alternatives indicate two separate types of adaptations -- pressure for quality reflects organizational adaption to professional norms, while financial pressure suggests the professionals' adaption to organizational values. (P. 70.)

This means, therefore, that in the effective system, each member feels "on top of" the organization; he is aware of the total system as it relates to its environment and knows how his job ties in with the total goals of the organization. This self and system awareness represents a strong sense of organizational identification for the person, and this experience when widely shared is an important dimension of organizational health. (P. 71.)

Pelz and Andrews (1966), in their work on scientists in organizations, also conclude that ". . . the scientists and engineers whom we studied did effective work under conditions that were not completely comfortable, but contained 'creative tensions' among forces pulling in different directions" (p. 7). They (Pelz & Andrews, 1966; p. 7) characterized broad features of the environment of the most productive scientists and engineers, as follows:

'Effective scientists were self-directed by their own ideas, and valued freedom. But at the same time they allowed several other people a voice in shaping their directions; they interacted vigorously with colleagues.

\*Effective scientists did not limit their activities either to the world of "application" or to the world of "pure science" but maintained an interest in both; their work was diversified.

\*Effective scientists were not fully in agreement with their organization in terms of their interests; what they personally enjoyed did not necessarily help them advance in the structure.

\*Effective scientists tended to be motivated by the same kinds of things as their colleagues. At the same time, however, they differed from their colleagues in the styles and strategies with which they approached their work.

\*In effective older groups, the members interacted vigorously and preferred each other as collaborators, yet they held each other at an emotional distance and felt free to disagree on technical strategies.

From the literature reviewed above, it can be said--in general--that productive and efficient R&D laboratories use organizational controls that embody pressures which are not dysfunctional, and their individual scientists, while preserving their own independence and interests, are flexible and dedicated to both the pursuit of quality in their work and to the welfare of their organizations.

#### B. TRENDS IN FEDERAL LABORATORIES

Glass (1970, p. 11) writes that "Probably no class of institution has been studied and analyzed, praised and criticized, organized and reorganized to the degree that has been the lot of the Defense laboratories." His report (Glass, 1970) provides a comprehensive review of the study, analysis, and evolution of Defense in-house laboratories.

The status and potential of Federal laboratories are also discussed in detail in the report of the hearings in March and April 1968 of the House Subcommittee on Science, Research, and Development, frequently referred to as the Daddario Committee. (Hereafter it will be referred to as the Subcommittee, 1968,) Pelz and Andrews (1966) also devote much of their book to scientists in government laboratories. More recently, the Defense Blue Ribbon Panel completed its investigation of Defense R&D activities with recommendations for major changes and improvements in the system. Especially germane to this report is the investigation of the Manpower Research Task Force of the Defense Science Board, which is nearing completion. Accordingly, the intent here is not to retrace this path of study and analysis, praise and criticism. Rather, the purpose of this section is to highlight salient characteristics of Federal and especially Department of Defense (DoD) laboratories that may have a bearing on the questions being examined in this report.

If professionals in good R&D laboratories identify with their organizations as mentioned above, surely those in Federal laboratories must do so with respect to the mission and purpose of their laboratories and the problems that are selected for investigation. The Committee on Federal Laboratories, for example, found that the single most important factor in laboratory morale was a sense of purpose on the part of each scientist and a sense that the results mattered to someone (Subcommittee, 1968). Harold B. Finger, Associate Administrator for Organization and Management, National Aeronautics and Space Administration (NASA), testi-

fying before the Subcommittee, stated that the NASA experience confirmed the value and importance of the purpose of an organization. He noted that it would be very hard for a research organization to succeed if its basic purposes and motivation seemed unimportant; on the other hand, a research organization which has an important and significant role to fulfill has a very good start in the critical process of building and holding a research competence. Dr. Donald M. McArthur, representing the Office of the Director of Defense Research and Engineering (DDR&E) before the Subcommittee, stated that the quality of a laboratory ". . . really comes down in the end to a number of criteria, but an overriding criteria is mission. Does it have a sense of purpose? Does it have high-quality people, and are they performing well?" (Subcommittee, 1968; p. 151).

With respect to the mission or purpose of Federal laboratories, Dr. Donald F. Hornig, director of the Office of Science and Technology, Executive Office of the President, spoke to the Subcommittee of some things that are not. He emphasized the point that these laboratories do not exist to "accumulate a pile of knowledge," that they do not "turn over the grains of sand in the Sahara Desert and examine them one by one," that theirs is not the purpose to do research for its own sake. Their task is to solve present problems and lay the foundation for the future; they must produce the ideas on which the next generation of their parent agencies' activities will be based. Accordingly, the laboratories need to have meaningful problems to work on, where the end results of what they do will be visible and on which they could be judged. He mentioned a "multiplier effect" of the

product of research activities. That is, their effect is on present and future programs of the entire Nation usually involving expenditures many times greater than those directly involved in the laboratory operations. Because of the "multiplier effect," Dr. Hornig stated that the utility of Federal laboratories must be viewed in the context of their overall contribution to national progress rather than in the narrow context of the administration of the laboratories themselves.

The mission or purpose of any government laboratory is operationally manifested in the problems that are selected for investigation and solution. The speakers before the Subcommittee were in close agreement over the fact that problem selection was the critical and most difficult task facing laboratories and especially the laboratory director. They noted that the input for making the decisions needed to come up from "the bench" and the laboratory management as well as from echelons above the laboratory. Hornig stated that it is not usually true that a person sitting at the top of the pyramid like himself, could say what the problems really are and what real technical problems are "soluble next year". He continued: ". . . whether you make progress depends on picking the right detailed problems, those which are ripe for solving at a given time. That requires keen technical insight." (Subcommittee, 1968; p. 9.)

Problem selection with respect to the Navy's personnel research laboratories is an extremely complex procedure that requires interaction between the highest echelons of Navy management, several levels of middle management, and the outlook at the "bench" in the laboratories themselves. Problem

selection depends, first, on establishing goals and objectives that define the total R&D program for the laboratories. This is accomplished, in turn, by considering guidance from program sponsors and planning documents, specific consumer requests, policy changes, and the results of task-force investigations (such as the recent Blue Ribbon Defense Panel recommendations). On the other hand, consideration in program definition must be given to the current ongoing program, the timing of requirements and expected completion of products, the capabilities of the laboratories, their stated missions, and overall funding constraints. Finally, room must be provided for self-generated ideas.

Once the goals and objectives of the overall program have been defined, problem selection will then depend on priority determination and an allocation of the necessary resources. Again, on one hand, the potential impact, significance, and payoff of the solution of a problem are prime considerations, along with requests from program sponsors and consumers. The current state of the art, requirements for additional research, and the probability of success are also important factors. Again, there are, on the other hand, the capabilities, specialization, and performance history of those who would work on a problem and the investment required in facilities, capital equipment, and personnel. Finally, there is a broad allocation problem of the division in resource commitment between research and development, to the extent that these can be differentiated (Gaver & Srinivasan, 1970). Underlying the entire area of problem selection is the question of how to do it rigorously.

Returning to the testimony before the Subcommittee, the most critical questions in the effective utilization of Federal laboratories, according to Hornig, were:

- (1) The choice of problems, their significance, and the feasibility of finding solutions through research and development;
- (2) the creation of capabilities in the laboratories which can, in fact, solve the most difficult problems; and (3) the translation of the results of the laboratories' work into action in either the public or private sectors. (Subcommittee, 1968; p. 9.)

Mission orientation in government laboratories usually means that there is a parent agency whose mission is being supported by the laboratory. Hornig (Subcommittee, 1968; p. 13), for example, has said:

An effective R&D program involves a dynamic give and take between the laboratory and its parent agency. It must not only carry out assigned tasks, but spell out the tasks which need to be performed; it must be a source of ideas for its parent agency and help the agency to put the laboratory's output into practice. All of this requires a very close identification between a laboratory and its sponsoring agency.

Mission orientation in R&D, on the other hand, may have both positive and negative aspects (Nichols, 1971). The positive aspects of this relationship were explained in the Bell report (Bureau of the Budget, 1962) as follows:

Federal operations, such as the governmental laboratory, enjoy a close and continuing relationship to the agency they serve which permits maximum responsiveness to the needs of that agency. Such operations accordingly have a natural advantage in conducting research, feasibility studies, developmental and analytical work, user tests and evaluations which directly support the management functions of the agency. Furthermore, an agency-operated research and development installation may provide a useful source of technical management personnel for its sponsor.

However, Hornig, speaking before the subcommittee, also admitted that almost all reports were in agreement that there is generally excessive administrative control and not enough freedom given to the directors of laboratories. He attributed this not only to civil service or other

rules but to past practices and procedures. He mentioned specifically as a difficult problem the relationship between military and civilian personnel in the direction of DOD laboratories, a problem which was accentuated by the policy of military rotation applied indiscriminately to technically qualified officers.

The difficulty in handling parent agency-laboratory relationships in a beneficial way and the persistence of problems in this area were commented upon by Glass (1970, p. 25) in reference to the findings and recommendations of the Blue Ribbon Defense Panel issued on 1 July 1970.

After almost nine years of a concerted effort to improve the climate and performance of in-house laboratories, the findings of the Blue Ribbon Defense Panel are somewhat depressing. Some people believe that, as long as in-house laboratories are organizationally imbedded deep within the Military Departments, efforts to achieve long-term improvements in laboratory operations are sure to fail. They feel that there is no way to protect the laboratories from the staggering overload of bureaucratic red tape and from diffuse, fragmented middle management levels that are apparently unable to delegate needed authority. On the other hand, many people believe that the close interaction of laboratories with their sponsors and their Department's needs would be unnecessarily perturbed if new organizational barriers were created.

The preceding discussion on the mission orientation of Federal laboratories and their parent agency relationships have involved the area of laboratory controls. That is, the mission orientation necessitates selectivity in problems to be investigated, while negative aspects of the parent agency-laboratory relationships are reminiscent of the dysfunctional aspects of pyramidal organizations described by Argyris. Are there characteristics of Federal laboratories that are also similar to the financial responsibility pressure mentioned by Hall and Lawler?

One possible means of exerting pressure of this nature was volunteered by Dr. William B. McLean, Technical Director, Navy Undersea Warfare Center, to the Subcommittee (1968). He felt that competition among laboratories in given areas was necessary so that the effectiveness of the laboratories could be demonstrated on a comparative basis. The process, he thought, would provide high incentives, high motivation, and the "only nonsubjective measure of effectiveness in R&D . . . ." (Subcommittee, 1968; p. 80). Daddario, however, suggested that it would be difficult to implement such a plan of duplicate or overlapping laboratory facilities so that Congress could effectively deal with it in the final determination and allocation of funds. McLean suggested that the situation actually existed in some areas--for example, the Air Force probably provided much competition to NASA.

McArthur, commenting on McLean's suggestion, took a different approach. He remarked that competition for funds exists within the DOD laboratory structure and that this runs the gamut from no competition for funds to laboratories that are almost totally competitive for funds. Noting that the latter tends towards laboratories becoming "job shops" with few or no longer range programs, he added that the optimum is somewhere between the two.

Mr. E. M. Glass, DoD Assistant Director for Laboratories, who was accompanying McArthur, commented that a laboratory should have to compete for at least 25 percent of its funds to stay healthy. The 80 to 90 percent of their funding that some Navy laboratories were competing

for from various customers (at that time) was thought to be excessive. He observed also that the situation with the Air Force laboratories, which received "block funding" and were not dependent at all on customers, could be made healthier if they had to compete for some of their funds. Competing for funds from a customer, he explained, resulted in a healthier situation by coupling laboratories more closely with their customers.

Thus, it is obvious that pressures not unlike "contract pressures" experienced in the non-Government laboratories also exist in the Federal laboratory structure. Accordingly, the organizational commitment of scientists should be a characteristic of Federal as well as civilian laboratories. That this is a characteristic of effective Federal laboratories has already been mentioned in some of the comments reported above.

The general environment of Federal laboratories, when it has been bad, has been due to weakness in the areas of pay and professional benefits, lack of challenging assignments and personnel recognition, and the arbitrary use of bureaucratic regulations with resulting frustrations and inhibiting effects (Glass, 1970). To this list might be added inadequate on-the-job support, as reported by the standing committee to the Federal Council on Laboratories. The standing committee also stated that such things as job titles, the retention of rights to patents, consulting fees and honoraria, security matters, and freedom to consult, lecture, and teach were considered relatively unimportant by the vast majority of 1,025 Federal scientists who were respondents to a questionnaire. (Subcommittee, 1968).

Characteristics of a desirable organizational environment that would maximize effectiveness were prepared by a Bureau of the Budget committee in conjunction with the Bell report (Bureau of the Budget, 1962). The basic requirements for such an organizational climate were (Glass, 1970, p. 33 and Appendix IV):

- Reputation and atmosphere
- Excellence of staff and its direction
- Importance of facilities and support
- Clarity, challenge and urgency of objectives
- Maintenance of professional caliber of operations
- Professional leadership by professionals
- Professional recognition and encouragement
- Encouragement and support of freedom of inquiry and method
- Advancement on merit
- Absence of unproductive regulations and reports

#### C. DIMENSIONS OF THE SCIENTIST-LABORATORY INTERFACE

The preceding analysis dealt with laboratories in general and more specifically with Federal laboratories. Some factors tending to enhance or inhibit the effectiveness of these laboratories were identified and discussed. When R&D laboratories are considered in the aggregate, it may be possible and even advantageous to think of individual laboratories as basic entities with characteristics and "personalities" of their own. From the standpoint of assessing the relative effectiveness of laboratories, this method may also be appropriate. In fact, a DoD program is in progress that takes this approach (Glass, 1969). Individual laboratories are being ranked on the basis of their effectiveness or excellence and the relationships of various laboratory characteristics to this measure of relative excellence are being examined. On the other hand, when one's concern is

in assessing the absolute effectiveness of a specific laboratory and also involves administrative and managerial approaches for upgrading that laboratory's capabilities, he must look for different items of information. He must look below the overall laboratory level to that area of dynamic interaction between the characteristics of the laboratory and the characteristics of its individual professionals who man the laboratory. This level might be called the level of the scientist-laboratory interface.

The characteristics of a laboratory might include such factors as its geographic location, whether it is located separately or within a larger military complex, overall size, budget and source of funds, subject area of research, location in the organizational chain of command, position on the research or developmental end of the R&D continuum, balance between in-house and contracted-out research, type and degree of external control exerted on the laboratory, and so on. These variables may be important in the comparative evaluation of laboratories. At least, they provide convenient and reasonably reliable categories for describing individual laboratories. But when one is dealing with one laboratory, many of these variables become constants which are of interest only to the extent that they define the boundary conditions within which the laboratory must operate.

On the other side of the interface, a great deal of research has been conducted regarding the characteristics, attitudes, and motivations of individual professionals in R&D. In the Hall and Lawler (1971) studies, for example, satisfaction of professionals surveyed was measured on a

hierarchy of human needs. Their questionnaire yielded scores for security, social esteem, autonomy, self-fulfillment, and a composite score which was a single average of the part scores. Job involvement was measured by an attitude scale. As in the Hall and Lawler studies, many other attempts have been made to find behavioral or output correlates of such personal attributes. These output criteria might be mobility, promotion, or some measure of volume, quality, and influence of an individual's work. But here again, in the case of a specific laboratory, one is not sure whether the previously found relationships will hold between the personal variables and the criterion variables. Why? First, effect of personal variables, such as satisfaction and job involvement, on output are dependent on other characteristics of the individual. For example, the relationship of satisfaction to some measure of output in laboratories may depend on the age distribution of the laboratory's scientists. Second, the relationship of the personal variables to the outcome variables is mediated by variables that are dimensions of the work or laboratory environment. And third, since much of this research is correlational, it is often difficult or impossible to infer the causal direction of the relationships established. For example, how much of job involvement is something intrinsic to the individual that he brings to the job and how much the result--the output--of his experience with the laboratory work environment?

Accordingly, when interest is centered on a specific laboratory, the crucial relationships are at the level of the scientist-laboratory interface. Detailed information is necessary which states how manipulation

of the alternatives available to laboratory management affect different scientists to bring about specific outcomes or results. It is especially important to discriminate between inputs and outputs. The laboratory's mission and tasks, externally imposed, are inputs which can be considered as constants, as previously explained. The scientist and what he brings to the laboratory in his person is the other input category. The laboratory environment or climate in which the scientist and the laboratory's organizational structures, procedures, and facilities interact might be called process. The result of the interaction is output, which includes the tangible products and services of the laboratory and also such secondary outcomes as experienced manpower and changes in the attitudes and outlook of the scientists. Thus, there is a mechanism for change, since the input (the scientist) will have been changed in the process for the next iteration. Similarly, the outcomes will provide feedback to the laboratory management for suggested changes in the operational environment. These categories--input, process, output, and feedback--might be called stages. They are schematically diagrammed in figure 1.

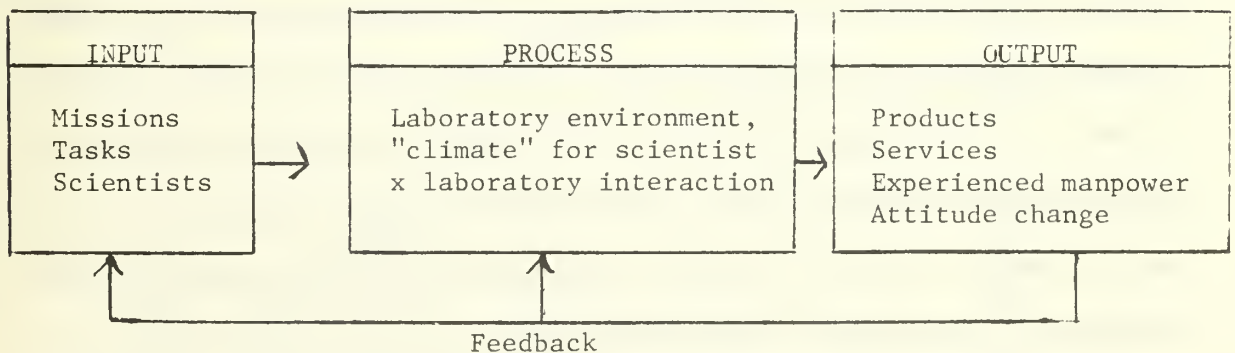


Figure 1. Simplified structure and dynamics of laboratory operations.

The stages can be further broken down into dimensions and variables as shown in figure 2. Of the input variables, education can be broken down into PhD, non-PhD, and Engineer categories. Pelz and Andrews (1966) used these categories and further classified their subjects into (1) PhD's in development-oriented laboratories, (2) PhD's in research-oriented laboratories, (3) non-PhD's in development-oriented laboratories not dominated by PhD's (called "engineers"), (4) non-PhD's in PhD-dominated laboratories (called "assistant scientists"), and (5) non-PhD scientists in research-oriented laboratories not dominated by PhD's (all in Government settings). Age is a continuous, quantitative variable which can be categorized, if desired. Orientation is an individual's preference for research or development activities. Specialization can be identified by an individual's area of specialization and further subdivided into the number of subareas in which he feels competent to do work. Professional style refers to the type of problems and the approach one prefers. The other dimensions--attitude, ability, personality, physical makeup--are named to fill out the list. Numerous other variables might be listed. Of the listed dimensions, education and age are parameters that can be most reliably obtained for personnel in a laboratory. Orientation, specialization, and professional style could be readily obtained by some form of questioning the technical staff. The others are more complex, more difficult to assess, and more unlikely to be related to the process and output variables in any simple, predictable manner.

The process variables are those that are characteristic of the

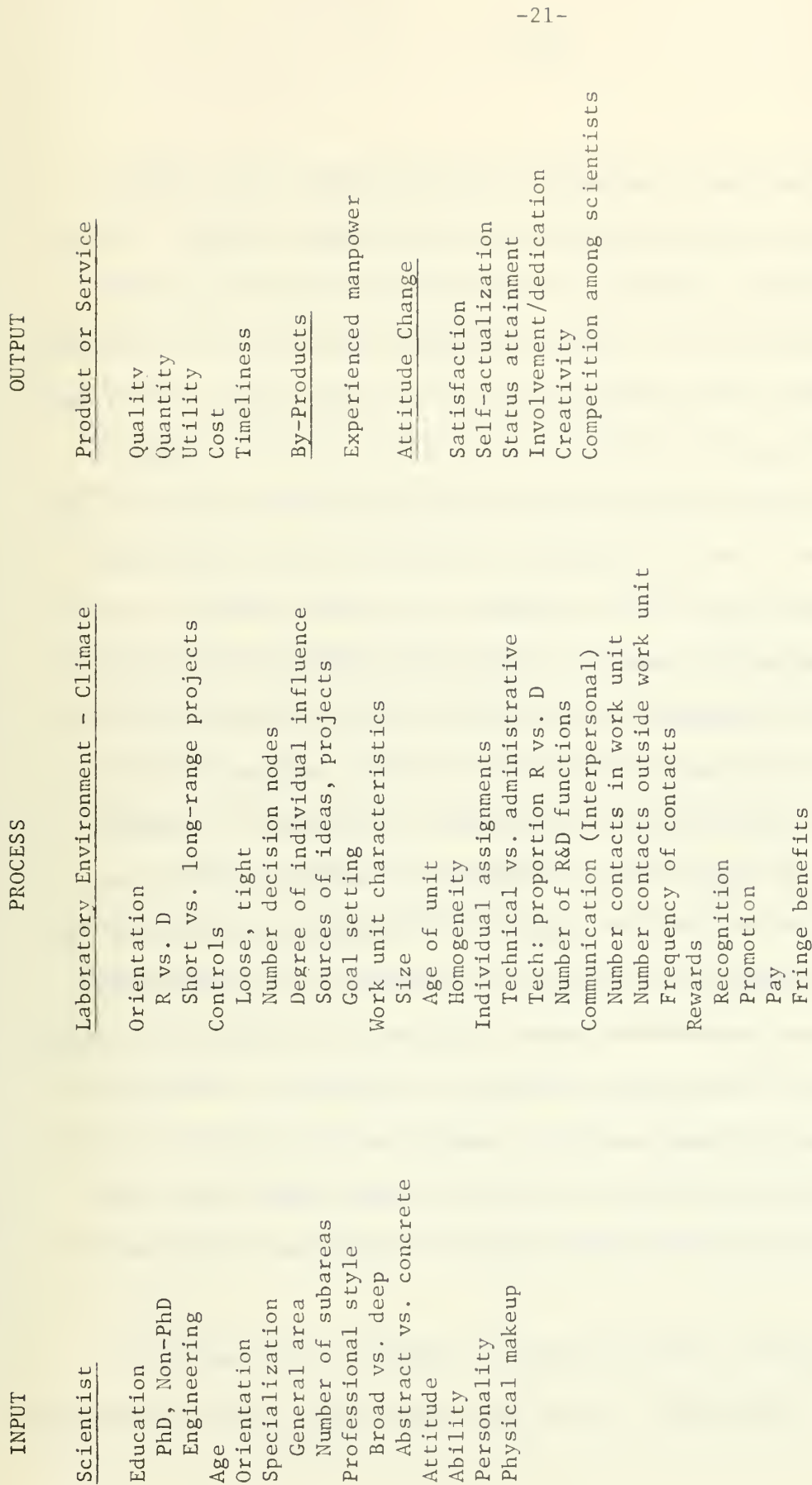


Figure 2. Breakdown of laboratory operations into dimensions and component variables within stages.

procedures and working environment of the laboratory. These are the elements that can be manipulated to change the output variables. Orientation refers to the research vs. development bent of the laboratory. The proportion of short vs. long-range programs could be another variable in this dimension. The important dimension of control can be identified by a number of variables such as loose vs. tight, number of checkoffs required for decision making, degree of influence assertable by the individual scientist in decision making, and sources of ideas and persons involved in goal setting. The time span of discretion might be another variable in the control area. Work unit characteristics can be defined by the degree of homogeneity or similarity of the individuals within the unit and the size and age of the unit. Individual assignments can be classified into the proportion of time spent in R&D work vs. administrative tasks, the proportion of technical time spent in research vs. development activities, and the number of R&D functions to which one is assigned. The communication structure and dynamics of the laboratory can be defined in terms of the number of contacts an individual has within his own work unit, the number of contacts he has outside the work unit, and the frequency of these contacts. Rewards can be looked at from the traditional aspects of promotion, pay, and fringe benefits; they might be identified by some less tangible forms of reinforcement, such as recognition.

The problem in using the process variables in any analysis is their method of measurement. On one hand, many values could be determined

by asking the management and by going through organization charts and other laboratory documentation. But research, and the practical experience of many persons, has shown that official statements and the opinions of the individual workers in the organization may vary considerably. Since the framework of analysis described above involves the interaction between the individual scientist and the laboratory operating environment, it would probably be necessary to ask the scientist to scale most of these variables from his own point of view.

Turning to the output variables, those listed under product or service require further operational definition before they can be meaningfully evaluated. This problem will be taken up in the next section of this paper. The attitude change variables, again, would have to be assessed on the basis of solicited individual opinions.

The foregoing list of variables borrows heavily from the monumental Pelz and Andrews (1966) work on scientists in organizations; their categorization by dimensions and stages and the inferred direction of causation do not. The description and discussion of general trends in the R&D field, and especially in laboratories, plus the detailed breakdown of the structure and dynamics within a laboratory, should provide the necessary background and framework for analyzing the specific problems posed in this study and making appropriate recommendations for their solution.

### III. EVALUATION OF LABORATORIES

#### A. PURPOSE, NEED, AND APPROACHES

Evaluation of the effectiveness of laboratory performance is a responsibility of those who manage the laboratories and the parent agencies that support them. While the need--or requirement--and even the desire to do so may be strong, the question of how to conduct the evaluation is one that has not found a universally acceptable answer. Even the question of "why" may not find a convergence of answers. Glass (1969, p. 1) writes:

R&D managers have been trying for many years to devise better yardsticks to measure the effectiveness and utility of laboratories. Most managers agree that such techniques are needed, but few can agree on how such appraisals can or should be made.

The evaluation of laboratories was a question of prime importance to the Subcommittee on Science, Research, and Development as an aspect of fostering the best utilization of Federal laboratories. Most of the witnesses before the Subcommittee were asked to comment upon their philosophy and approaches to laboratory evaluation. In addition, the witnesses were asked to submit answers to written questions provided them following their appearance before the Subcommittee. One of the questions dealt with the problem of evaluation. The views expressed in their statements provide excellent insight into the mechanisms of evaluation and the philosophy behind the approaches taken.

Hornig (Subcommittee, 1968; p. 22), provided a broad overview of the appraisal of laboratories:

Appraisal of in-house laboratory performance is a normal responsibility of agency management. . . .

Procedures in use in the Government . . . involve such techniques as visits to the laboratory by teams of agency management representatives; evaluation of results by agency management and--especially where more basic research is involved--by outside advisory groups; and continuing reviews of laboratory operations through reports, audits, conferences, day-to-day contacts, and so on. In some cases, development activities lend themselves to controlled scheduling procedures such as PERT, but such control methods are generally not applicable to research near the basic end of the spectrum. Evaluations are necessarily qualitative rather than quantitative to a considerable degree, and involve judgments based on such factors as experience and comparison with good practice elsewhere.

The prime objective is not the application of any specific set of administrative techniques, but the elevation of the quality and efficiency of administration of Federal laboratories totally, including such matters as maintenance of challenging and relevant laboratory missions, elevation of salary scales to attract first class managers, and securing sufficient freedom for laboratory managers.

McLean (Subcommittee, 1968; p. 84) brought out the difficulty of finding a proper criterion to measure in-house laboratory effectiveness that could be compared with the profit-loss ledger of the profit-oriented civilian enterprises. He also mentioned the need for subjective appraisals and review committees, as follows:

For any organization or individual to feel successful there must be some mechanism for measuring the degree in which they have fulfilled their goals. In an organization which is profit-oriented, such an evaluation is straightforward, rigorous, and simple. If the figures are in the black, all associated with the organization are happy. If they are in the red, or tending toward the red, then something must be done to rectify the situation. Government organizations, military organizations, educational institutions, and research and development activities, whenever they are adequately removed from the profit-making pressures, have a more difficult time in establishing a proper evaluation of the effectiveness of their processes and results. For

all such organizations I believe the evaluation must be on the basis of competition similar to that involved in making a profit. The fact, however, that results cannot easily be expressed in terms of a single variable, such as money, tends to make the evaluation process much more difficult. Governments are judged by history, and military organizations by wars. These are very harsh and final judgments and do not provide a very adequate, self-rectifying mechanism.

In essence, the appraisal of contractor and laboratory performance is limited by the capabilities of the individuals available to perform the appraisal. Of necessity, an appraiser must be a person who has been very successful in the field being evaluated. Yet, every appraiser has his own set of biases and believes that his own approach is the only correct approach. The competitive system is the only appraisal system that leaves open the possibility of innovation.

In spite of these difficulties in evaluation, the Navy is setting up technically competent review committees to review laboratory performance. The effect of these committees on laboratory performance has yet to be evaluated.

In his testimony before the Subcommittee, Astin acknowledged the need to have some mechanism for "rating" the many laboratories within his organization, the National Bureau of Standards, and implied that the purpose of such ratings was to do something about strengthening ineffective management and leadership and to encourage those that were strong. In his written comments, however, he presented (Subcommittee, 1968; p 69) an excellent discussion of the mechanism of program review as an evaluative process:

. . . An annual or sometimes more frequent series of reviews of all of the significant programs of the Bureau are made by operating personnel to top NBS officials. Generally programs are closely related to one or several organizational units. The program of each division is

also subject to review at least annually by Advisory Committees of the National Academy of Sciences. Finally, an outside evaluation of the Bureau as a whole is made by a Statutory Visiting Committee which reports annually to the Secretary of Commerce on the efficiency of NBS operations.

At the program reviews those responsible for the program discuss their past accomplishments, present work and future program plans. Information is given and questions raised concerning the adequacy and competence of the staff and future requirements; similar matters are covered in respect to facilities, equipment, funds and other resources. Program requirements and priorities are discussed in respect to their relationship to national needs. On the basis of all of the above, the present health and future outlook of Bureau programs are assessed by NBS officials, priorities are set, and appropriate allocations and commitments are made. Occasionally decisions are made that some programs of substantially diminished importance have outlived their usefulness. When such decisions are made, the staff members involved are reassigned when possible or reduced in force when reassignment is impractical.

Other speakers before the Subcommittee also referred to project and program reviews and evaluation panels and advisory groups as mechanisms for conducting the assessment of laboratory effectiveness. Some, particularly the NASA representative, emphasized continuous and close technical/professional communications between the headquarters and the laboratory as a means of appraising laboratory performance. The comments of MacArthur (Subcommittee, 1968; p. 151) were of particular relevance to this study:

When we evaluate the quality of a laboratory there are many criteria we use. The three services, the Air Force, the Army, and the Navy, have advisory groups which periodically review the programs of the laboratories and come up with recommendations in terms of whether they are above standards, below standard, fine, mediocre, whatever they might be.

We also look at whether they have meaningful missions.

Secondly, within the Department of Defense at the D.D.R. & E. level where I come from, we look at programs

from a programmatic standpoint, from a technical standpoint, and at that point we look at the contributions the laboratories are making to that program.

Thirdly, as you no doubt know, some of our laboratories are involved at only one end of the R. & D. spectrum, research and technology. Other laboratories are involved throughout the whole R.&D. spectrum through engineering development and test and evaluation.

Now, one of the criteria we use when a laboratory is involved at the research and technology end of the spectrum is how much of their output over the last few years has been incorporated in some of our systems development programs.

In a laboratory that is involved in engineering development, we look at the effectiveness of the systems or hardware they have developed or managed, and, lastly, we look at the individual laboratory director's independent research program and look at how he has managed his funds, what he has done, where he has invested them, but the real test is how much business he got based on those investments he has made.

Among the supplemental questions addressed to MacArthur, was one that asked him to explain the DoD system for evaluating contractors that provide R&D and to state to what extent the system should or could be used in appraising the work of the in-house laboratories. MacArthur, in his reply, described the DoD Contractor Performance Evaluation (CPE) Program, a system designed to provide an orderly and uniform technique of determining and recording the effectiveness of contractors primarily for hardware development and production. In evaluating the appropriateness of the CPE procedure for in-house laboratory appraisals, MacArthur's comments (Subcommittee, 1968; p. 180) were particularly illuminating:

For those contracts where the end product is new technology or new scientific findings, CPE can be utilized,

if the Military Departments consider it desirable. However, a less formal evaluation of such contracts is generally utilized. This is usually in the form of a subjective appraisal by the project monitor.

The CPE System appears to be most suitable for evaluating specific programs for which there are meaningful performance standards and mileposts. I might add that similar criteria are utilized to evaluate the hardware development laboratories, although in a different form. In other words, the CPE System is designed to evaluate performance on a specific well-defined project or program. Its purpose is not to evaluate over-all organizational effectiveness.

Much of the work of Defense laboratories is in the areas of long-range research and technology. Thus, a system such as CPE would not be generally applicable. One advantage we see in the establishment of military problem oriented weapon centers is that the utility of their output can be measured fairly directly on a real-time basis. Practically everyone knows and can measure the tremendous productivity of a NOTS, China Lake. Its output goes directly into the military inventory. On the other hand, the output or product of a research laboratory is much more difficult to assess. Many years may pass before the utilization of new science or technology can be measured meaningfully.

The principal method used for Defense laboratories is peer rating or evaluation, either by in-house people, those on the outside, or combinations of both. This is only part of the story, however. Program evaluation in terms of need, priority, technical content, and similar factors probably have a greater bearing upon the appraisal of laboratories than direct institutional evaluation. Through program evaluation, one usually makes decisions on resource allocation which ultimately determine the future of that laboratory responsible for the program execution.

The comments to the Subcommittee extracted above were representative of the others who testified. The needs and purposes of the evaluations seemed to fall under the following categories:

Determine the quality and efficiency of the administration  
Evaluate the meaningfulness of programs

- Determine the health and future outlook of programs
- Look for challenging, relevant missions; adequate pay of professional staff; and freedom for the laboratory manager
- Set priorities and determine allocation and commitment of funds
- Look for laboratories and/or programs that have served their usefulness to shut them down
- Shore up the management and leadership where necessary; give encouragement to good leadership
- Provide guidance to the laboratories
- Determine adequacy and competence of staff and future requirements
- Determine adequacy of facilities, equipment, funds, and other resources.

They all tended to agree that evaluation of the research and technology end of the R&D spectrum is the difficult problem, that this has to be done subjectively/qualitatively, and that some sort of panel of experts is an appropriate mechanism. There was an underlying current that program evaluation and institutional evaluation are different but that program reviews over a period of time can serve the function of institutional reviews. Perhaps the distinction between program reviews and institutional reviews lies in the criteria available for evaluation. Program reviews have more specific goals against which progress towards those goals can be evaluated. Institutional reviews, however, emphasize such intangibles as overall quality, relevance of work attempted, and technical competence. If this were so, then the distinction between program reviews and institutional reviews might be one of performance vs. quality. It should be noted that good performance on the part of a laboratory does not necessarily ensure effectiveness or quality in the product, even in hardware systems. (This matter will be further elaborated under the discussion of evaluation criteria.)

## B. ADVISORY PANELS

Since the use of advisory panels seems to be generally accepted as a method for evaluating laboratories, a more detailed examination of the process would seem to be in order. While the panels are usually termed advisory, the term may mean anything from the simple lack of directive authority, at one end, to advisory in the literal sense of the word at the other. Usually, the distinction is closely associated with the level of the convening authority of the panel, tending to be more closely allied to direction monitoring, and decision-making processes when it is formed by, and reports to, a headquarters above the laboratory. Another dimension underlying the panel system is the constitution of the panel--that is, the source and types of persons making up the panel. And finally, closely related to these two dimensions, is that of the basic purpose of a panel.

The following interchange between Daddario and MacArthur at the Subcommittee's (1968, p. 152) hearings highlights the use of advisory panels at the highest levels in the services:

Mr. Daddario. You talk about judgment by peers. Who are they and how do you get them together?

Dr. MacArthur. There are three--let me address each service. In the Air Force we have a board of advisers which is a panel of the scientific advisory board and they are from the outside. They involve individuals from the industrial world, individuals from the universities, and from nonprofit organizations.

In the Navy we have the technical evaluation board which is a part of the Naval Research Advisory Council.

Again, all members of this advisory board or technical evaluation group are from outside the Department of Defense.

The Army is different in that they have a group which is composed solely of all in-house individuals and they perform an appraisal every 3 years. We call it the triannual survey group.

These are the advisory boards I referred to.

Mr. Daddario. How are the laboratory directors involved in the evaluation, if at all?

Dr. MacArthur. Well, these advisory boards, they do more than read papers. They actually visit the labs. They talk to the laboratory directors and the key people at the laboratories to see what they are involved in, what they are doing, what their mission is, what they have contributed in the last year, and what they intend to work on in the following years, and why.

One of the biggest problems we have been having in the past years was that some of these laboratories weren't involved in important questions. That is one of the things we have been stressing, that they have to get more involved in important military problems.

Here, while there is obviously interaction between the panels and the laboratories, the purpose of the panels seems generally to be to advise the responsible command above the laboratory level and to encourage the implementation of the command's policies--e.g., become more involved in relevant military problems. The evaluative nature of the panel is especially evident in the Army's case by its constitution. On the other hand, the following exchange between Daddario and Astin (Subcommittee, 1968; p. 50) very definitely implies a panel that is responsive at the laboratory director's level and serves at his discretion.

Mr. Daddario. How do you bring the individuals together and how do you allow the people who are involved in the Federal laboratories to participate? Yesterday we had some testimony on the need to do this more often than we do, not only because you can get different points of view, but also because laboratory directors would find out more what was going on and they could improve their own management activities.

Dr. Astin. Well, it is my feeling that every laboratory manager or director should have some responsibility for formulating at least a portion of his program. In general the laboratory supports the mission of the agency, and

to be effective, it has to be responsive. But if the program is to be dynamic and effective, then formulation of some portion of this program has to be under the control of the laboratory manager.

At the same time it is desirable, I think, for him to have mechanisms for seeking advice from experts in the technologies involved. In general advisory committees to laboratory managers have proved very helpful.

The discussion in section A, above, also emphasized the role of panels in program formulation and evaluation. One of the "purest" examples of the use of panels for such purposes is the practice in some Federal agencies to assemble panels of specialists to evaluate proposals for Federal support. The problem that may arise when scientists themselves are used as the panel members is explained by Nichols (1971, p. 33):

Some representatives and senators have been asking searching questions about what they see as an overelaborate "buddy system" masquerading as a scientific "judicial system". All too few people in Congress understand the enormous, largely unpaid efforts invested by scientists in the panel review system used by most agencies to evaluate proposals for federal support. Worse still, the dedication of most of these reviewers to high quality is just not grasped by a number of influential members and staff of congressional committees. Log-rolling, it seems to some congressmen, is being increasingly substituted for what were once rigorous standards of scientific quality and productivity.

\* \* \* \* \*

Despite the valiant and often insightful efforts of a few scientist-analysts, Congress sees little progress being made in solving the difficult "apples and oranges" problem of allocating resources to and within various federal R&D areas.

Nichols' comments suggest that advisory panels play an important decision-making role in the Federal R&D effort. When this is the purpose of a panel, Gideonse (1970) adds another dimension to the use of panels

for program evaluation. He maintains that the scientist-panel approach to decision making is only proper for non-mission-oriented agencies and those supporting fundamental research. But when agencies have more specific missions, persons selected to serve in an advisory capacity must have the expertise required to make the decisions involved, especially of a policy setting nature.

Thus, the use of advisory panels in the management of R&D activities is a complex procedure involving at least a consideration of the purpose of the panel, the agency that it supports, and who shall constitute the panel. Finally, as mentioned in section II A, top-level committees formed as "overseers" of research may well be a symptom of deterioration in the R&D process and not a cure (Argyris, 1968).

#### C. CRITERIA

Criteria to be used for evaluating laboratories are closely linked to the purpose of the evaluation. In addition, criteria are of little worth if there is no way to provide measurements which indicate a position on the criterion for a given laboratory. Thus, such terms as measures of effectiveness, figures of merit, cost/benefit ratios, and so forth arise to fill this need. Unfortunately, the possibility of finding appropriate measurements--"yardsticks," according to Glass--become more remote as the purpose of the evaluation becomes global and abstract. In fact, it becomes difficult just to find appropriate criteria, much less methods for measurement, when such is the case. Take, for example, the desire to determine the technical excellence of a laboratory. What criteria does one use to

to do this? And what measurements are to be taken to denote the position of a laboratory on the criterion?

One approach is to look for intermediate, more readily quantifiable criteria as estimates of the more general, abstract criteria. This approach assumes, of course, that the relationships of the intermediate or part criteria to each other and to the higher level criteria are known. Usually this is not the case. This approach, when carried to the extreme, results in measurements of manner of performance--or simply, performance--rather than measures of quality (Hatry, 1970). Typically, such measures involve quantity of output, rate of production/output, costs, manpower utilization, adherence to schedules, adherence to standards and specifications, and so forth. As indicators of workload and managerial efficiency the measures may be appropriate. A dramatic example of the meaninglessness of such measures involves the gross national product (GNP), presumably an indicator of the quality of life in the nation. A family makes a contribution to the GNP when its mother dies: the GNP goes up because more expenditures are necessary to procure the services which the mother formerly provided for nothing (Clausen, 1971). A similar, although not so dramatic an example, can arise when program reviews are used for the evaluation of a laboratory and progress on a PERT or GANTT chart is used as the criterion of the quality or utility of the work being performed. In fact, the opposite is more likely to be true: quality is sacrificed to meet the milestones.

Another problem in evaluating R&D work in personnel research is the fact that it deals with human beings and their value systems (Gideonse, 1971). Consequently, the findings, results, and recommendations of research--

even the topics chosen to be researched---are evaluated against social and political criteria of a very general nature over and above the scientific quality of the work. To find, as the Navy did some years ago, that volunteers from certain areas of the United States who were very young and high-school dropouts created so much trouble that the Navy would be better off not enlisting them has the seeds of a very touchy, social-political problem. On the other hand, if personnel and behavioral science research does not come to grips with socially relevant, politically loaded questions, it will be criticized for skirting the problems that "really count." It is understood that the Taskforce on Manpower of the Defense Science Board is taking a very hard look at the adequacy of Defense manpower research in respect to the pressing, social-political problems that involve the Department of Defense. The problems involved in finding adequate criteria for research and program evaluation dealing with the "quality of life" are thoroughly explored by Clausen (1971) and Hatry (1970).

Another, and often unrecognized, area creating difficulty in assessing the effectiveness of personnel research and human factors/man-machine R&D requires mention. This is the fact that the absence of problems in a completed system is a sign of good work in these disciplines. For example, an operator in a complex system may find information displayed so it is readily monitored; controls of the right size, shape, and location; and work-space and environment conducive to extended-duration performance in comfort. His training, job aids, work procedures, and workload are adequate. He has ready communication channels to other operators or superiors when necessary. Years of research on small, apparently insignificant research

problems have all contributed to the knowledge required to achieve this situation. An experienced and talented group, thoroughly conversant with this knowledge, is required to put this wealth of information into the system design. Yet current research of the same type, looking to the future, may be severely criticized by the unsophisticated observer as, for example, "analysis of variance" research on insignificant or irrelevant problems with little prospect of payoff. It is indeed a difficult problem to determine the payoff or effectiveness of long-term research at or near the basic science end of the R&D spectrum.

Returning, again, to the hearings of the Subcommittee on Science, Research, and Development, some of the criteria mentioned by those testifying were as follows:

- 1) Comparison of a laboratory with "experience"
- 2) Comparison with "good practice"
- 3) How much of the output of research and technology has been incorporated into system development programs
- 4) Effectiveness of the system hardware managed by the laboratory
- 5) Amount of subsequent business received from an initial expenditure of independent laboratory research funds
- 6) Peer ratings

The majority of these criteria depend on judgment, partly or completely, in the evaluative process. The third listed has often been called "implementation," and is largely anecdotal. A direct, simple approach to implementing the "implementation" criterion is highly likely to be seriously criticized as in the case of Project HINDSIGHT (Radnor, Rubenstein, and Tansik, 1970). Item 4 is obviously the ultimate criterion, but the only valid measurement

is performance in the operational environment. Ignoring the difficulty in doing this, there is an added problem of evaluating partial criteria for laboratories that support the system manager. For example, when a personnel laboratory provides the personnel subsystem for a system, there is no way to evaluate precisely the contribution of the personnel subsystem to the total system effectiveness. Item 5 is also closely related to implementation, and has a strong judgmental component. Accordingly, all but the last mentioned criterion reflect the context in which the other criteria are often used--namely, in advisory panel reviews. Peer ratings will be discussed below under methods.

Additional criteria which have been used in appraising and evaluating R&D can also be compiled from other sources (Hall & Lawler, 1971; Hoshovsky, 1970; Pelz & Andrews, 1966; US Atomic Agency Manual, Appendix). A partial listing includes the following, which are shown irrespective of the distinction between performance measures vs. quality measures:

- Inventiveness in advancing technologies
- Quality and originality of ideas and proposals
- Discernment in determining when lines of inquiry become unprofitable
- Stature of individuals and organization within the scientific community
- Overall manpower levels in relation to work output
- Effectiveness of personnel policies in attracting and retaining qualified technical staff
- Net change in R&D budget during the last year
- Number of new internally funded projects
- Percent of projects meeting schedule
- Number of projects/contracts renewed
- Percent of projects meeting cost budget
- Ratio of contracts won to contracts proposed
- Number of papers in professional journals
- Number of patents and patent applications

- Number of technical reports
- Frequency of visits to laboratory
- Quick fixes, problem solution events
- Citations in the literature
- Requests for laboratory reports, services
- Percent of project completed to those started

#### D. METHODS

Two methods of evaluation have been mentioned in the discussion. One was the use of advisory panels, and the other was peer ratings. Since advisory panels use ad hoc procedures which depend on their purpose and constituency, as previously discussed, they will not be further considered for methodology. Accordingly, this section will concentrate on the peer rating methods. Before entering into an examination of peer ratings, however, two other approaches suggested by the criteria involved should be mentioned.

The first is system effectiveness as an indicator of the effectiveness of the laboratory which held primary management responsibilities for the system. It was said that personnel laboratories provide input only in the form of subsystems which cannot be evaluated in any precise manner for their contribution to total system effectiveness. This is true in the case of military hardware systems. On the other hand, the personnel laboratories have prime responsibility for certain soft systems, such as computer models for personnel planning, personnel selection devices and procedures, training packages and computer-aided course materials. Traditional measures of worth could be applied in such instances--measures such as reduction in reaction time, workload, and costs and an increase in efficiency. But in

this initial examination of the laboratory evaluation problem, this area will not be further elaborated. Two reasons might be given for this decision. In the first place, such programs are less than a majority of the total laboratory program. Second, there is the complicating factor of false starts, seemingly interminable programs, and junked programs of this nature that must also be considered in measuring the effectiveness of the laboratory with respect to its own system development projects. Finally, as an initial procedure, a peer rating method could be devised to obtain judgmental evaluations of the value, quality, and effectiveness of programs in this area.

The other area of evaluation that might be applied to the products of personnel research laboratories stems from the implementation criterion. The approach would be to determine the degree to which products of the laboratory have been accepted into system designs or into system design methodology. This is also a complicated area in respect to an effectiveness evaluation of the laboratories. For example, implementation of a product does not necessarily mean that greater effectiveness was achieved. The opposite could be the case. And again, the projects that are terminated prior to implementation decisions must also be considered in the evaluation. Implementation of a laboratory product in a particular application might also be less than 100 percent of the laboratory package, or the product might be significantly modified by the user before and during implementation. And finally, lack of implementation by the user agency does not necessarily mean that the product was ineffective, since many

factors are involved in the nonacceptance of innovations in the Navy (Mecherikoff & Mackie, 1970). Again, as with the system effectiveness measure, products which might be evaluated using the implementation criterion can also be assessed judgmentally using peer rating methods as the initial step.

The evaluation of laboratory effectiveness and quality by peer ratings in the DoD stems from the work of Pelz and Andrews (1966). Their objective was not an evaluation of laboratory effectiveness, however. Rather, they were interested in the organizational and individual, personal variables that lead to effectiveness among scientists in R&D settings. But obviously, the quality of individual work in an organization is clearly related to institutional effectiveness. Accordingly, a method to evaluate the effectiveness of individuals in an organization is essentially a method for the evaluation of the quality of the institution itself. In fact, Hall and Lawler (1971) had R&D organization managers rate the quality of their individual scientists and then these ratings were combined into a global rating of laboratory performance effectiveness. They did this to circumvent the difficult problem of having the laboratory director rate himself by rating the quality of his laboratory.

Pelz and Andrews had senior scientists and managers in R&D organizations rate their scientists on two criteria. These were: (1) Their contribution to general technical or scientific knowledge within their field (in the last 5 years) and (2) their overall usefulness in helping the organization carry out its responsibilities (within the last 5 years).

Now the difficult problems that accompany a mass rating scheme such as this result from the fact that judges do not know all the ratees, do not know them equally well, and do not have equal confidence among themselves as to the fineness of the discriminations they could make (number of rating units) among the ratees. Usual rating methods, however, cannot handle gaps in the data well and require a consistent scale of measurement among judges. As a consequence of these constrictions, considerable forcing of the raters is resorted to. The raters or judges are forced to rate all ratees using the same scale categories; sometimes judges are even required to place an equal number of ratees in each category (to prevent them from all piling up at the high end). Thus, the convenience of the investigator is satisfied with unknown, but perhaps considerable, loss in the validity of the ratings. That is, adding noise to a set of data, even if it is done in a systematic way, does not always clarify the signal.

Pelz and Andrews (1966) and Andrews and Pelz (in preparation) describe how they were able to devise a program based on an earlier paper by Ford in the American Mathematical Monthly. The Ford method allowed a judge to eliminate those ratees he did not know, create as many rating categories as he wished, and to place as many individuals as he desired in any one category (but not more than one-third of all individuals being rated). As a result of the freedom permitted, the judges were able to space their subjects over the categories they had created and could evaluate approximately 50 scientists on the two criteria in less than one hour without obvious strain. This flexibility of their rating procedure was undoubtedly a major

factor in the amount and usefulness of the data Pelz and Andrews were able to obtain.

The Ford procedure is based on a win-loss matrix which shows the probability that each ratee will be ranked above or below every other ratee. Then, by an iterative process, weights are derived for each ratee so that, when ratee-ratee comparisons are made using the weights, the original matrix will be recaptured. Ordinal scaling (ranking) of the weights then provide the ranking of each ratee. The program is written in Fortran for an IBM 360/40 system and will handle up to 130 judges who may use up to 130 ranked categories in evaluating up to 130 objects (Andrews & Pelz, in preparation).

Dr. Maurice Apstein of the Harry Diamond Laboratories used a modified Pelz technique in which laboratories instead of individuals were ranked by peers (Glass, 1969). The peers, or judges, were professional technical people with considerable experience in R&D. The rankings were made to serve as the criterion variable against which to evaluate the size of the contract effort administered by a laboratory; that is, interest was in determining the effect that the size of the contract effort administered by the laboratory had on the general overall excellence of the laboratory.

The current DoD study (Glass, 1969) in this mold was initiated by Mr. Evan D. Anderson of the Office for Laboratory Management, ODDR&E, before his transfer to the Federal Commission on Procurement. The study is much broader in size and scope than Apstein's. There were 250 judges

in the sample with up to 400 being planned for the ultimate sample. The breakdown of judges was as follows:

- (1) DoD laboratory directors
- (2) R&D managers and technical specialists within the Federal Government
- (3) Industrial technical specialists, consultants and professionals from nonprofit organizations
- (4) Scientists and engineers in academic institutions
- (5) Technical specialists in DoD program management and system project offices

The larger number of judges permitted their assignment into the foregoing categories for analysis of rankings. Accordingly, judgments of laboratories could be made on rather specific performance factors in contrast to global rankings of "technical competence." This permits a finer analysis of the competence of the various laboratories and of particular interest are the rankings of the customer's of the laboratories.

As with the Pelz and Andrews study and the Apstein study, the objective of the current DoD study is not simply a relative ranking of the laboratories. Here again, the rankings--now available on different ranking criteria--provide the basis, the dependent variable, the criterion against which many factors relating to R&D management will be analyzed with the ultimate purpose of achieving a better understanding of the R&D process in order to administer it better.

#### IV. INNOVATION IN RESEARCH AND DEVELOPMENT ENVIRONMENTS

There is little in the scientific literature on innovation in R&D laboratories. Perhaps the reason for this is that scientists and technical personnel are by the very nature of their professions assumed to be innovative. Why do research on innovation among innovators? According to Argyris (1968, p. 354),

There is, in short, almost nothing that can be said about redesigning and changing research and development organizations that is based upon empirical research and experimentation within these types of organizations. It is ironic but regrettably true that the very organizations charged with research and innovation have been responsible for generating little research and less innovation about their own effectiveness.

Because of this situation, factors that might be important for innovation within laboratories will be derived from a consideration of implementation problems in reverse. That is, problems that arise in the implementation of R&D products in user organizations often involve innovations in techniques, procedures, and/or materiel. Innovations within a R&D laboratory, then, might be considered a special case of implementation in which the innovation is developed elsewhere and brought into the laboratory (even though the innovation might have been developed by the laboratory, itself).

The problems of implementation associated with innovative items can be studied from several approaches and to varying depths of detail. Mecherikoff and Mackie (1970) analyzed the problem of acceptance of innovations in the Navy as a problem in attitude change. A review of the extensive literature on attitude change, a major area of personality and

social psychology, did not provide them with concrete answers or handy tools for overcoming negative attitudes toward innovations. While their study is couched in the technical terminology of attitude change, their structuring of the problem and recommendations--based on case studies as well as the literature review--is essentially a tract on salesmanship. So while their recommendations--actually guidance--regarding appropriate procedures seem to be fundamentally sound, they, like principles of salesmanship, are probably only as good as the skill of the salesman (the change advocate) in any particular situation.

The factors involved in attitude change regarding an innovation are listed by them as involving at least the following: (1) The person advocating the change, (2) the communication or message that accompanies the effort, (3) the group factors which affect an individual's propensity for change, (4) individual characteristics that result in different responses to innovative efforts, and (5) situational factors. Any one of these factors can take on many values, and there are complex interactions among them. Accordingly, any specific occurrence of an innovation problem may have an infinite number of alternative courses that the attitude change process might take. Because of the impossibility of placing probabilities on these alternative courses with any degree of confidence, an approach that attempts to break down the innovation problem into such fragmented detail does not have practical applications. The approach, of course, may have considerable heuristic value.

Those involved in the Northwestern University Program of Research on the Management of Research and Development have taken a more molar

approach to the implementation of R&D products (Radnor, Rubenstein, & Tansik, 1970). Considering the implementation problem as a special case of the general phase-transition process in R&D, they reach essentially the same impasse as Mecherikoff and Mackie. They state that "Many new products, product lines, and technologies fail initially, and sometimes remain failures, because of the inability of the organization and its members to adapt their attitudes and behavior in a manner required by the new venture" (Radnor, Rubenstein, & Tansik, 1970, p. 969). They list the following factors that underly implementation problems in the R&D environment (Radnor, et. al., 1970, p. 971):

1. Recognition of the need for an item.
2. Willingness of the individuals in the receiving unit to interrupt ongoing work to handle something new.
3. Technical mismatch in understanding of the specifications of the item.
4. Mismatch in understanding of objectives of the project or task.
5. Pre-existing relations of trust or confidence between the parties to an implementation transaction.
6. Degree of involvement in stages of a project.
7. Self-interest.
8. Urgency.
9. Perceived threat.
10. Level of managerial support.
11. Point in time at which a management commitment is made to the project--i.e., the decision to set up a formal project mechanism.

Their model of the phase-transition process that is implementation is more specific and worked out in fuller detail compared with the large "black box" diagrams of Mecherikoff and Mackie. Nevertheless, it is still a theoretical model of the process and not a practical, workable tool.

Following their critical review of the implementation problem, they list some methods that have been reportedly successful in implementation, but warn that they have been used in projects that have failed, too. The methods are (Radnor, et. al., 1970, p. 989):

1. Assuring that there is a clear and recognized need for the results at the time the project is undertaken.
2. Involvement of the ultimate user of the results early in the process, and maintaining communication throughout the project.
3. Focus of the direction or strategy for the project in an individual or a small group that can review and make decisions about changes in direction or level of effort.
4. Having top management support and enthusiasm.
5. Allowing or encouraging researchers to follow projects into application and make careers there, if they so desire.

They conclude, from the wide diversity of methods used and the lack of consistent cause-effect relations between methods used and project success, that much more research is needed in the area before there will be a reasonable theory of implementation, let alone a handbook or set of algorithms for carrying out implementation. Carried over into the implementation of innovations within an R&D laboratory, an even stronger conclusion can be made: there are no administrative and managerial practices that are guaranteed to succeed.

What, then, could management do to bring innovations into the laboratory with at least some modicum of success? In the first place, the guidance that can be gained from a study and application of principles developed in documents, such as those cited in the discussion above, should not be ignored. But there would seem to be a lesson that can be obtained

from the two lists provided by Radnor et. al. that is especially appropriate for R&D management. If we remember that the implementation problem as discussed arises from the user environment, the picture may not be so bleak in the R&D environment. That is, implementation in reverse is not exactly the same as implementation in the forward direction because innovation in the R&D environment is the accepted way of life and the path to success. It is administered out of the environment by the dysfunctional control processes so aptly described by Argyris. Innovation in the laboratory should, then, follow as a direct result of good administration of the laboratory that creates in its individual members a need for innovation, the willingness to give time and effort to it, an involvement in innovative projects, a feeling of a sense of urgency for the development and use of innovative approaches, and an opportunity to cash in on successful application of innovative techniques and procedures. These factors, taken from the Radnor, et. al. lists, are but a specific example of the characteristics of positive laboratory pressures described earlier from the works of Hall and Lawler: quality, time, and financial responsibility pressures and a deep sense of involvement in the total life framework of the laboratory. As shown by Merchikoff and Mackie, the pressure points where action could be taken to accomplish these ends are the individual participant and the group and situational factors. Referred to the laboratory environment, these are precisely the dimensions of the scientist-laboratory interface shown in figure 2 and described in section II c, above. The problem for the laboratory manager is to determine which of the many interfaces, when

properly manipulated, will provide the most payoff in the direction desired. An approach that may solve this problem satisfactorily in the Navy's personnel research laboratories is given in section V B, recommendations for innovation.

## V. RECOMMENDATIONS

### A. RECOMMENDATIONS FOR EFFECTIVENESS EVALUATION

It is known that the usual management procedures for ensuring adequate performance of a laboratory, such as coordinating conferences, reports, person-to-person contacts, and so forth, are fully used in the management of the Navy's personnel research laboratories. Further elaboration of this area as a means for effectiveness evaluation is not contemplated.

From the preceding discussion involving the use of advisory panels to evaluate the quality and effectiveness of a laboratory, it is recommended that such a panel or panels be established.<sup>1</sup> The purpose of such a panel should be to assess the health of current programs; the quality of personnel and the techniques being employed; the relevance and meaningfulness of the total program configuration of the laboratories; and methods being employed to upgrade facilities, skills, and capabilities. The panel should include technical personnel and representatives of consumer organizations, as in the case of the panel for the current DoD peer rating effort in view of the broad spectrum of projects worked on in the laboratories. The reporting level will probably be at the Bureau of Naval Personnel level, but the activities of the panel should emphasize interactions with personnel at the laboratory level to ensure a feeling of participatory management on the part of the laboratory people. It would seem advisable to have a subpanel or another panel at the laboratory director's level that is composed strictly of technical personnel to provide advice and guidance to the laboratory as requested.

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1. While this study was in progress, a Laboratory Advisory Board for Personnel Laboratories has been established under the aegis of the Naval Research Advisory Committee (NRAC). The primary purpose of the advisory board is to provide NRAC background information for its advice on Navy RDT&E matters to the Assistant Secretary of Navy (R&D). Its specific areas of evaluation are similar to those discussed here. The members are all technical personnel under the chairmanship of Dr. Joseph W. Rigney, Department of Psychology, University of Southern California.

In the case of individual laboratories, some estimate of the quality or effectiveness of its products--rather than the laboratory as an institution--is desired. Currently, the formal reports of the laboratories are accompanied by an "Evaluation of Report" form which requests the reader to evaluate the report and mail in the evaluation form. A similar form exists for end-product evaluations that are not in the formal report series. The report evaluation asks the reviewer to rate the report as low, average, or high on several categories which are related to usefulness, timeliness, accuracy, and format factors. In addition, open-ended questions and room for comments are provided. The questions also emphasize an evaluation of the usefulness of the report and the usefulness of the laboratory's products. Unfortunately, the return rate of the forms is essentially nil. A similar form was in use by the US Air Forces Human Resources Laboratory, with the same result. The latter has been discontinued.

It is suggested that the Pelz-Andrews technique be modified and applied to the laboratory's products as the rated items in lieu of individual professionals or individual laboratories. The products could be rated at the program (task area) level or at the level of formal reports that are terminal, comprehensive reports of a project. Probably the latter would present a problem in selection or a problem in too many products for evaluation. The decision would have to be worked out with the personnel R&D management structure. It is further suggested that the panels be of two distinct types. A type-one panel would be composed of technical personnel from the user agencies who could be expected to be familiar with the products of the laboratories. This would provide the all-important consumer appraisal

of a laboratory's products. A type-two panel would be composed of only technical/professional personnel from the laboratory. This would provide the important factor of laboratory participation in the evaluation process, and indirectly a voice in the laboratory's R&D program. The technical panel could be supplemented by personnel from outside the laboratory who are familiar with its products to provide another facet to the evaluation. All of the panels would not need to be implemented. The consumer panel would probably provide management with the most useful information with respect to effectiveness. The in-house, type-two panel would be the easiest to implement.

The criteria for the ratings would be different for the two panels. The type-one panel would use two criteria which could be called (1) usefulness and (2) influence. The usefulness criterion would include the area of evaluation portrayed on the Evaluation of Report form and would emphasize short-term, direct applications of the product. Included in the criterion would be factors such as usefulness, timeliness, completeness, accuracy, adequacy of data, adequacy of approach, convenience of format. The specific wording of the criterion would be worked out with personnel research, management personnel. The second criterion, dealing with the influence of the report, will emphasize its long-term usefulness according to its potential influence on concepts, planning, and decision-making in the user agencies.

The criteria for the type-two panel would also number two: (1) technical-scientific value and (2) mission appropriateness. The first criterion would be similar to that used by Pelz and Andrews regarding the work of

individual scientists. The product would be rated for its value in contributing to knowledge in the field and especially its value in furthering the work of the laboratory. The second criterion would permit the laboratory personnel to express their thoughts on what the laboratory should be doing, considering its general mission. In other words, the panel would rate its programs as most appropriate or representative of what the mission calls for. The mission statements, as of this writing, are those in DDR&E Management Analysis Report, MAR 70-4 (pages 87 and 95).

The method of analysis would involve the use of the University of Michigan program, available from the Survey Research Center, for the Ford analysis. The derived weights for the products analyzed could serve as the dependent variable for further analyses based on characteristics of the raters and of the rated items. Such analyses would provide a fuller understanding of what factors constitute the effective and noneffective products or programs of the laboratories. They would also provide input for managerial and administrative practices to enhance the implementation of innovative techniques and procedures.

A difficult problem in carrying out the recommended ratings would be an appropriate definition of the "consumer" for a type I panel. Because of the diversification of the areas of specialization of the Navy's personnel research laboratories, potential customers will not be a homogenous group. Accordingly, rankings obtained through a type I panel will reflect the constitution of the panel. In addition, there may be an insufficient commonality of items rated to provide a reliable ranking over a majority

of the items. In the extreme case, each of a few judges may rate completely different items, for example. Probably the best way to overcome these potential problem areas would be to use many raters (as in the DoD laboratory study mentioned previously). But here, practical considerations and the limited number of potential raters may present other problems. In the final analysis, however, the rankings by a type I panel constitute a managerial tool for providing needed information, and any bias in the constitution of the rater sample should reflect the desires and purposes of management in conducting the ratings.

The procedure of evaluating laboratory products by peer ratings could be done at periodic intervals, say approximately three years, to maintain a feel for the quality and effectiveness of the laboratory's work.

As long-range programs, it is recommended that studies be initiated to determine how to assess the contribution of personnel research laboratory products to total system effectiveness and how to use implementation as a criterion to evaluate effectiveness of the laboratory's output.

## B. RECOMMENDATIONS FOR INNOVATION IMPLEMENTATION

Interviews at the Navy's personnel research laboratories indicate that many specific attempts to upgrade the professional excellence of the laboratory are being made. They include the procurement of outside speakers, tutorials on specific techniques, attendance at professional meetings, bringing in specially qualified reserve officers for their "summer tours," sponsoring symposia, attendance at short courses, and the other commonly used procedures. In one instance, for example, the developers of the automated operational sequence diagramming technique at San Diego went to the Washington laboratory to put on a tutorial on the method. The effects of these attempts is not known but assumed to be beneficial. (The usual case.)

It was concluded in the section on innovation (section IV D) that innovation in the laboratory is a problem in manipulating the appropriate variables in the scientist-laboratory interface to bring about the climate that would, of itself, create a motivation for innovation. Then, any specific innovative attempt or project would have a greater chance of succeeding. The problem lies in deciding which set of variables to manipulate.

In order to determine what set of variables to manipulate, one must know the important interactions and their outcomes of the input and process variables shown in figure 2. A comprehensive study showing important relationships of this type is the Pelz-Andrews monograph previously referred to on many occasions. A simple way to answer the question of what to do lies in obtaining measurements on the important variables of the Pelz-Andrews study for a particular laboratory and then going to the study to

determine what manipulations will produce the desired climate. For example, if one group of PhD scientists turned up in a predominantly research-oriented work unit in which the decision controls for any one person were very few, he would find from the Pelz-Andrews monograph that having four decision-controls (decreasing freedom!) resulted in a higher volume and quality of output for such scientists. The indicated action is obvious.

Such an approach could be taken at several levels of complexity with respect to data collection. A level-one analysis (simple data collection) would use the following variables:

Individual variables: Age; education; time since BA/S, MA/S, PhD; and area of specialization.

Work unit variables: Identification of unit, size, predominant orientation.

The combination of the individual variables with the work-unit variables will lead to many practical management procedures for moving the climate toward greater effectiveness of the work unit, including implementation of innovative methods. The value for these variables could be obtained from individual records, organizational charts, and unit charters. In addition, management could provide estimates as to some of the control variables that might apply to the work units, thus enrichening the analysis. If the laboratory products evaluated in the peer ratings can be traced by source to the work units, the relationship of work-unit characteristics to quality of output could be analyzed using a multivariate procedure described below.

A more complex level of analysis would involve the creation of appropriate questionnaires to obtain data from individual scientists in the

laboratories. Of particular interest would be the obtaining of additional dependent measures for multivariate analyses. These would be the number of papers published and presentations made in a specified period of time and the number of laboratory reports authored/coauthored in that period. Again, it would be desirable to identify the work unit and the individual with specific products or program areas that have been peer rated. Multivariate analyses of the input and process variables using the peer ratings and individual production as the dependent variables would provide a rich picture of the factors within the laboratory associated with effective and noneffective individuals and work units. A multivariate technique, Multiple Classification Analysis, has been obtained from the Survey Research Center that is particularly adaptable to this analysis (Andrews, Morgan & Sonquist, 1969). This technique and the computer program listed were used for the analyses in the Pelz and Andrews study of scientists in organizations.

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